SCR Inlet Maldistributions – Their Effects & Strategies for Their Control

Kevin J. Rogers
The Babcock & Wilcox Company
20 South Van Buren Avenue
Barberton, Ohio 44203-0351
e-mail: kjrogers@babcock.com
Telephone: (330) 860-2185
Fax: (330) 860-1384

Summary

The distribution of flow, temperature, and reactant concentrations at the inlet to an SCR reactor influences overall performance, as well as the outlet ammonia and NO_x profiles. The level of acceptable reactor inlet maldistribution varies depending on performance duty. High-duty SCR designs, with low slip and high NO_x removal, require the greatest uniformity.

System designs for high uniformity levels will vary depending on the supplier's technical approach and design philosophy. A variety of gaseous mixing, ammonia injection and gas flow correction strategies can intertwine to satisfy the dictated inlet criteria in an operationally stable manner. No single design approach is best for all cases.

For most projects, reactor velocity distribution requirements have been achievable without much difficulty. However, due to its impact on the NH_3/NO_x profile, flow uniformity at the ammonia injection plane can be more stringent and thus more difficult to achieve.

While full-load temperature distributions are also typically manageable, problems do occur when economizer bypass is needed to maintain reactor temperature at lower loads. These bypass cases routinely generate the worst temperature profiles. Aggravating the problem is sub-optimal merging of the bypass gas into the mainstream flow where large initial stratification can make mixing difficult.

NH_3/NO_x molar ratio uniformity is often the overriding factor, especially for high-duty designs. Strategies for mixing before and after the ammonia injection process can improve the long term stability of the blend. More effective and stable dosing of NH_3 to the NO_x flux profile at the ammonia injection plane reduces the need for intensive downstream mixing. Achieving the most stringent uniformity levels relies on the manipulation of options available in flow correction, ammonia injection and static mixing. The goal is to overcome the difficulties presented by flue arrangement, system pressure drop and ammonia injection grid placement limitations.

The challenge of dispersing ammonia from injection point to injection point differs from that of overall blending in the gas stream. The dispersion length required for a given injection point concentration will vary depending on the design of the ammonia injection grid, injection point area concentration, and the intensity of downstream mixing. In the simplest case, when ammonia dispersion is the only goal, the system design can be accomplished with minimal or no static mixing. If mixing is incorporated, it is more local than global in relation to flue area, and the associated mixing elements are smaller with their effect dissipated over a shorter distance.

The larger the variations in outlet NO_x and temperature profiles, the greater the need for blending across the flue cross-section. While mixing devices produce an initial performance over the length of the device, many rely heavily on downstream turbulent profile generation and dissipation to complete the blending function. Thus, the greater the side-to-side or top-to-bottom blending needs, the more important available downstream flue length becomes. Larger mixing element flow channels can require greater downstream lengths to fulfill the complete mixing potential. A side benefit is action that rapidly reduces the scale of NH_3 segregation when fewer and larger ammonia injection points are incorporated in the flow field.

Large cross-duct blending can also increase downstream velocity disturbances. The mixer design will impact this relationship. Those that rely on larger eddy formation will tend to disrupt velocity profiles more than those providing a more simple lateral displacement of gas volumes. In any case, the downstream velocity characteristics of a mixer can influence the proximity limits between the mixer elements and the velocity profile assessment plane. In some cases, depending on the degree of velocity imbalance entering the mix zone and the degree with which turbulence is directed towards localized mixing, a properly designed mix zone can simultaneously improve both chemical component distribution profiles and gas velocity profiles. In the end, synergy between mixing and flow distribution is the key to process optimization in a typical restricted space design.

Static mixing is not a panacea that eliminates any need for flexibility in AIG flow adjustment. In the attempt to either achieve extreme levels of molar ratio uniformity and/or when compensating for larger-scale NO_x and flow profile variations, the use of mixers themselves may not fully compensate and an injection grid that allows sufficient adjustment in NH_3 flux patterns becomes extremely useful. Modeling of projected dispersion patterns from an ammonia injection zone allows an analysis of controllability versus injection zone quantity and configuration. In general, the use of modeling to map the performance characteristics of the discrete components within the system improves a system supplier's ability to select and choose the most appropriate design path in the most expeditious manner.